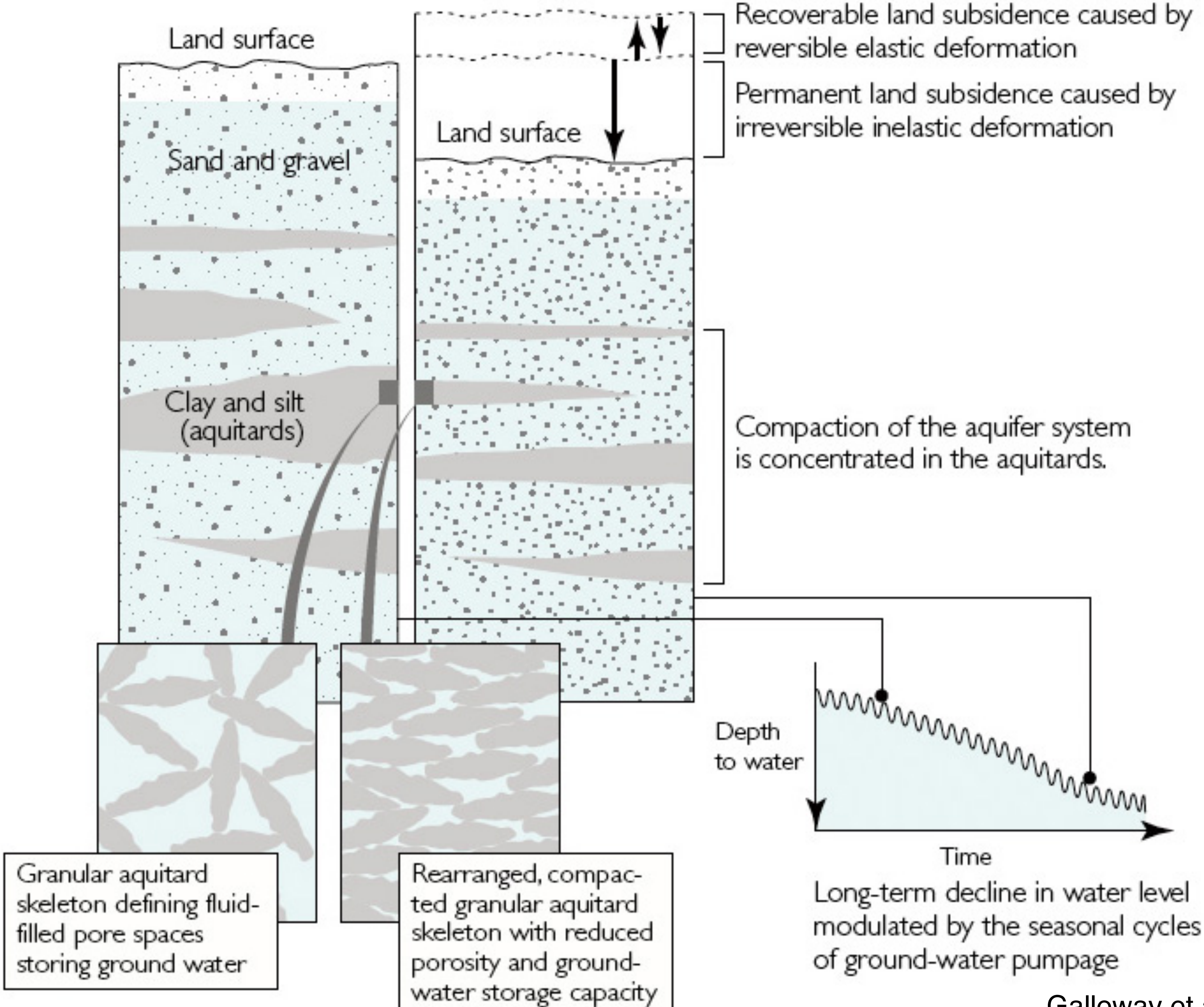
Remote Monitoring of Groundwater with Orbital Radar

Tom G Farr, Zhen Liu
Jet Propulsion Laboratory
tom.farr@jpl.nasa.gov

Groundwater from Space

- Groundwater is becoming a more important part of water resources
- But knowledge of the groundwater level is not uniformly available
- Wells provide some monitoring capability, but there are political and practical difficulties
- Interferometric Synthetic Aperture Radar (InSAR) can provide information on groundwater levels by measuring surface deformation caused by withdrawal and recharge of aquifers
- The deformation also causes problems for infrastructure such as aqueducts and trains
- We are developing information products for water managers, the public, and hydrologists including animations, maps of ‘hot spots’, pixel histories, and regional maps of groundwater change

Hydrology 101: Aquifer compaction

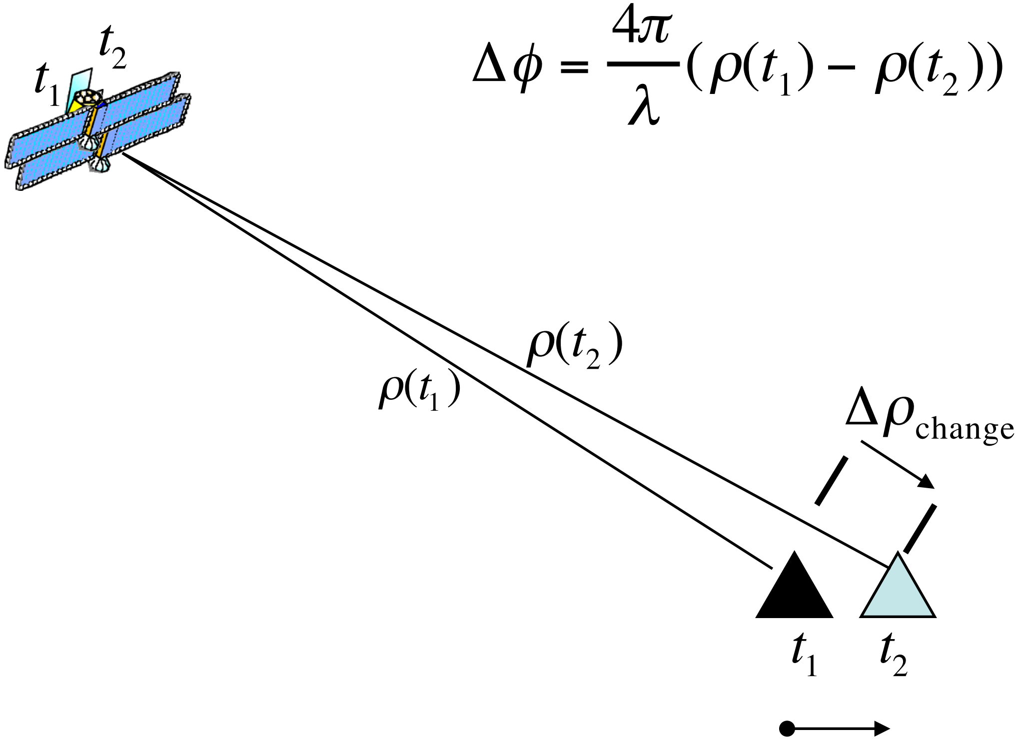


Galloway et al., 1999

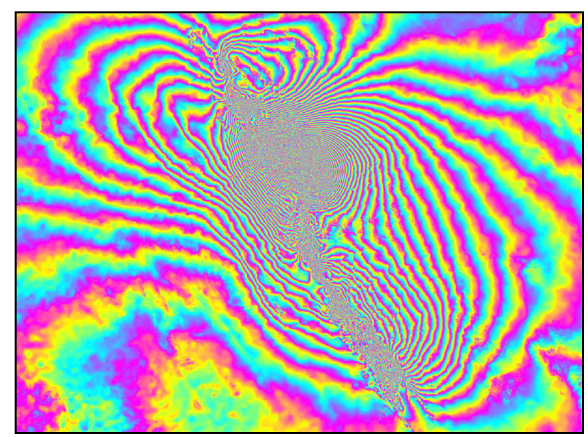
Interferometry 101: Deformation maps

When two observations are made from the same location in space but at different times, the interferometric phase is proportional to any change in the range of a surface feature.

$$\Delta\phi = \frac{4\pi}{\lambda}(\rho(t_1) - \rho(t_2)) = \frac{4\pi}{\lambda}\Delta\rho_{\text{change}}$$



Surface Deformation Phase

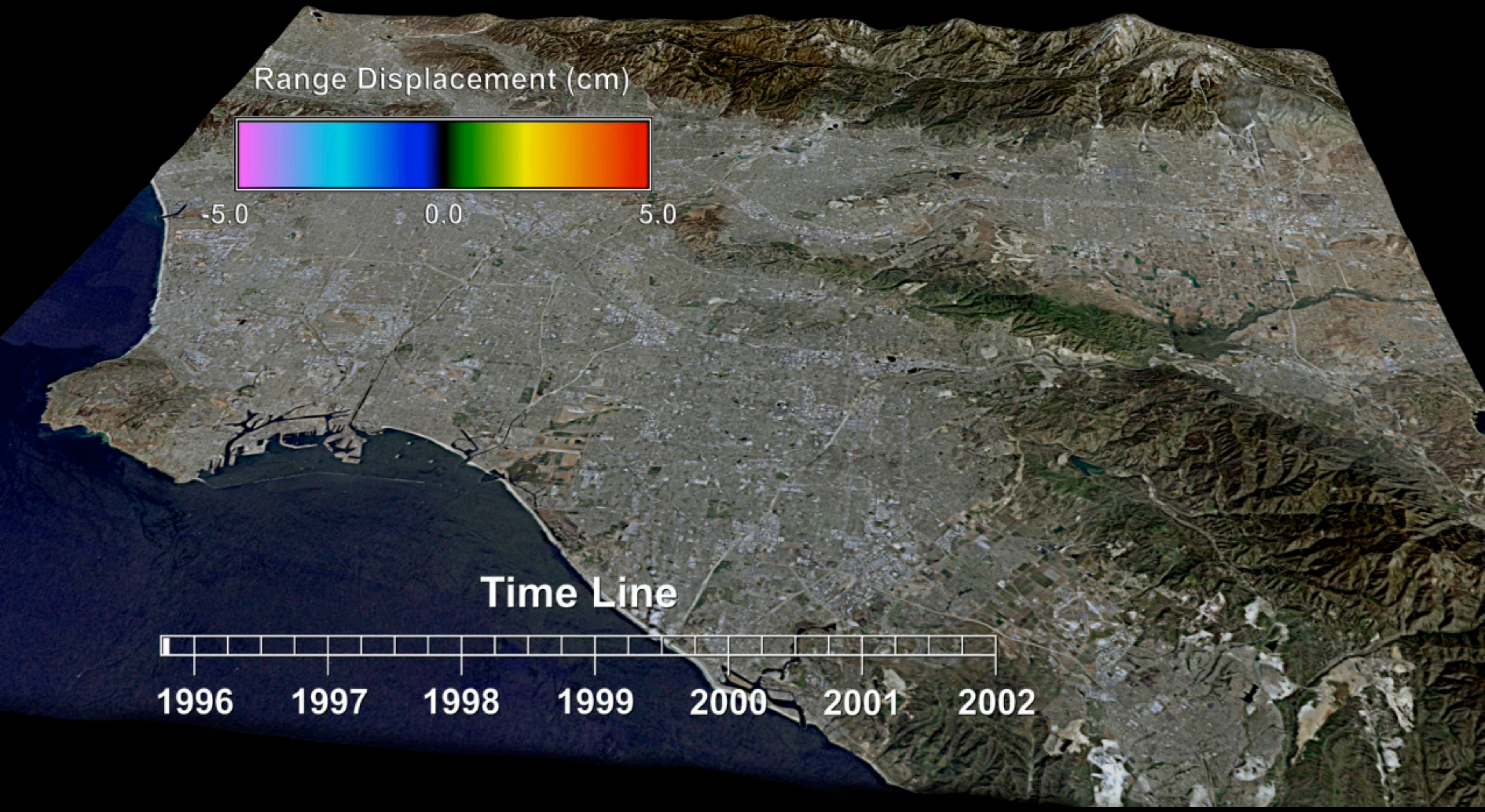


Orbital Radars for Interferometry

Satellite	dates	resolution (m)	swath (km)	incidence angles	minimum revisit (days)	band*/pol
ERS 1,2	1991-2010	25	100	25°	35	CVV
Envisat	2002-2010	25	100	15-45°	35	CVV, CHH
PALSAR	2006-2011	10-100	40-350	10-60°	46	L-quad
Radarsat 1	1995-2013	10-100	45-500	20-49°	24	CHH
Radarsat 2	2008-	3-100	25-500	10-60°	24	C-quad
TerraSAR-X	2007-	1-16	5-100	15-60°	11	X-quad
Cosmo-Skymed	2007-	1-100	10-200	20-60°	<1	X-quad
PALSAR-2	2014?	3-60	50-350	8-70°	14	L-quad
Sentinel	2014?	20	250	30-45°	14	C-dual
NI SAR	2020?	35	350	15-60°	12	L-quad

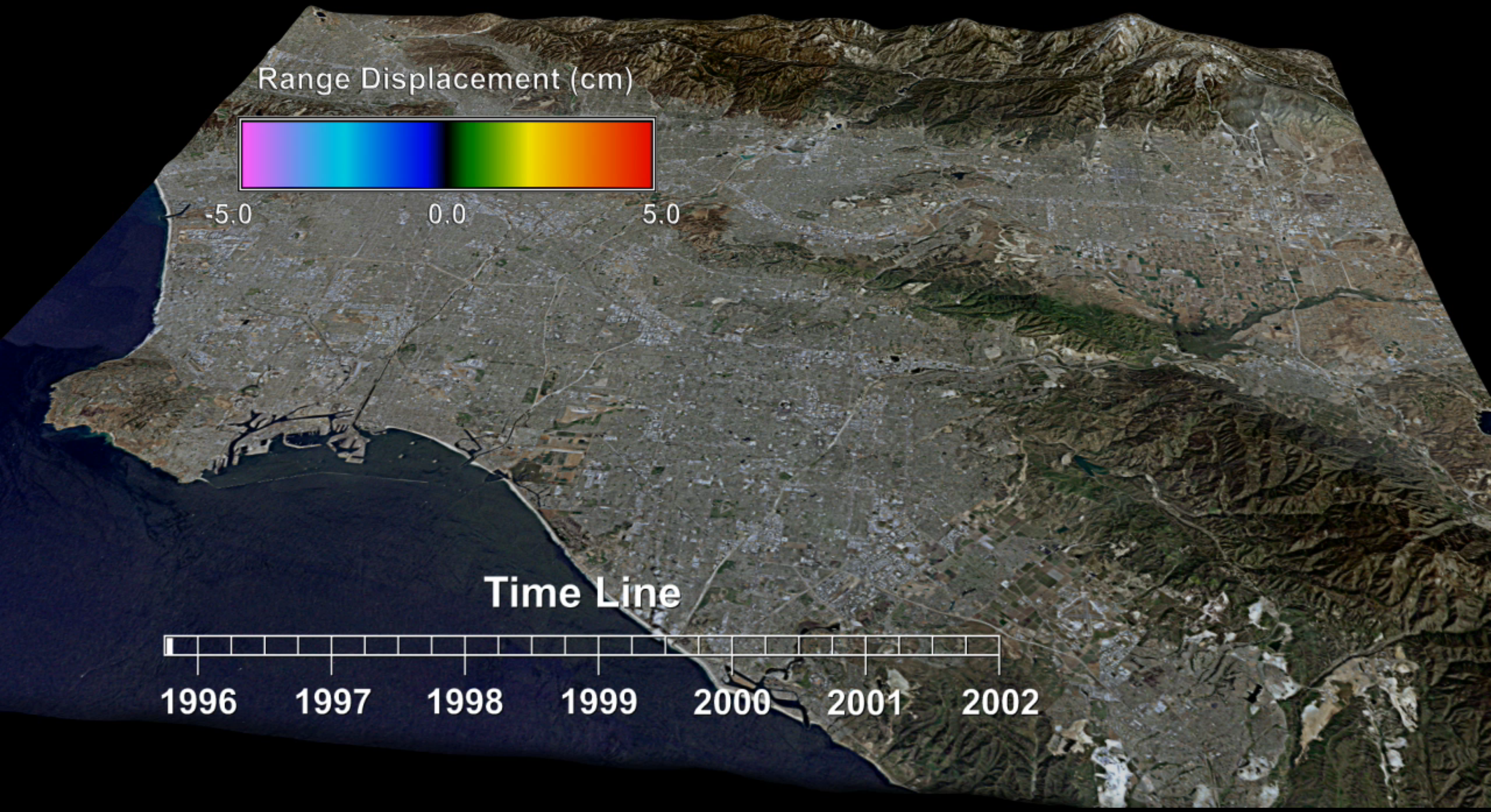
* wavelengths: X ~ 3 cm, C ~ 5 cm, L ~ 25 cm

Monitoring LA Basin



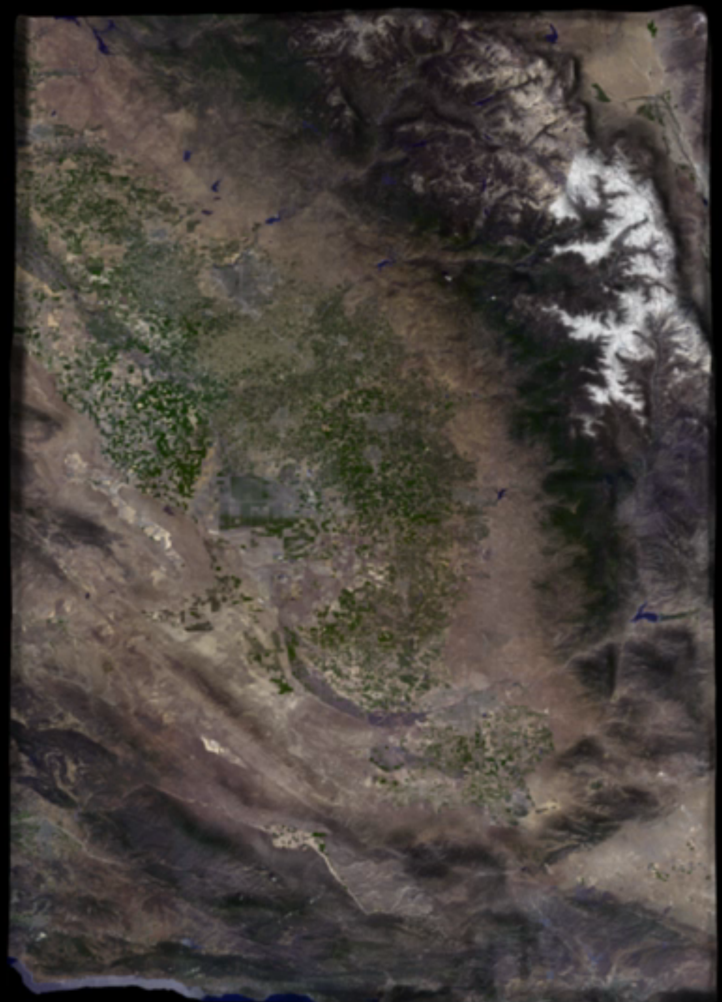
Paul Lundgren, Vince Realmuto, JPL

Monitoring LA Basin

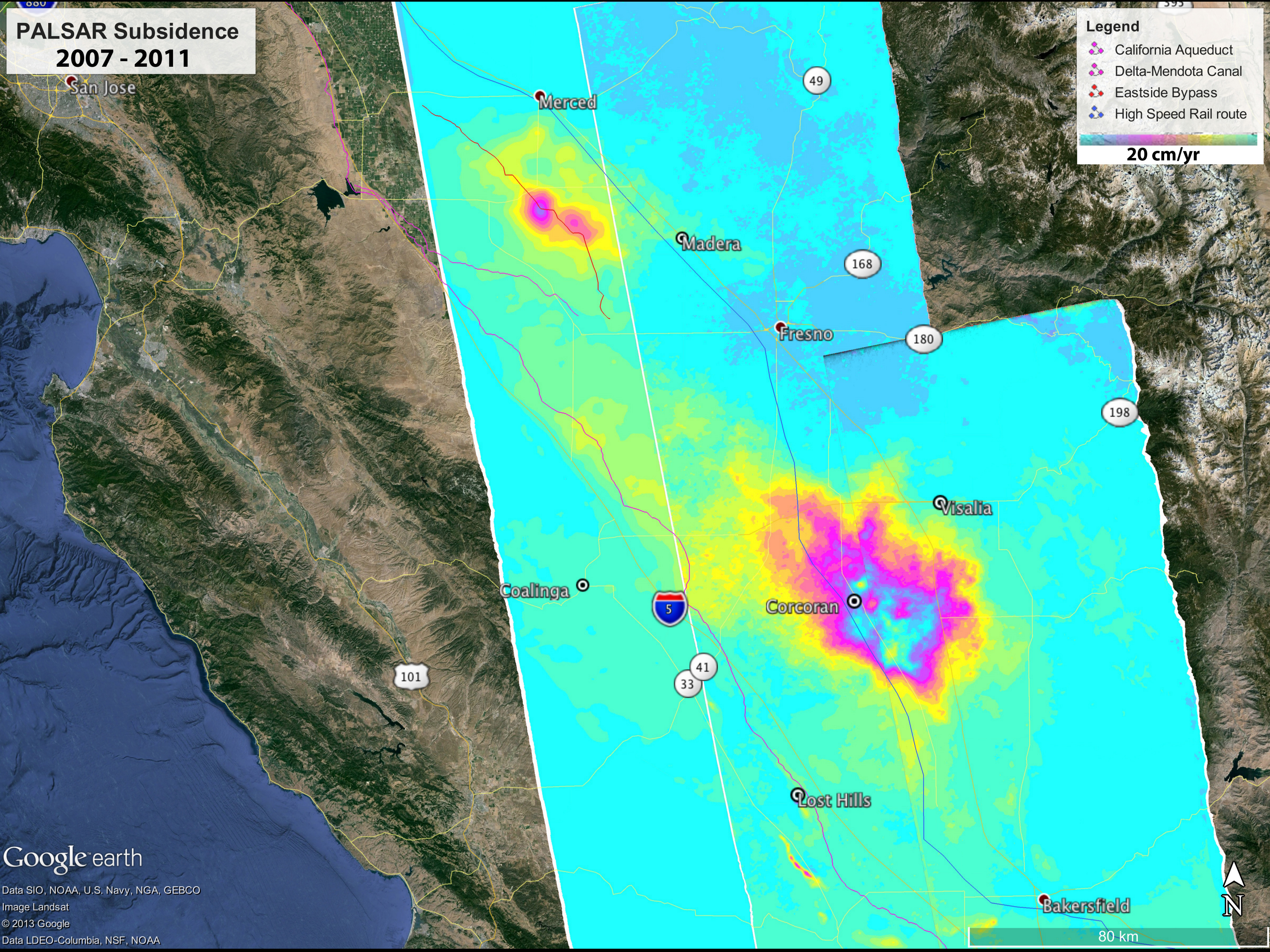


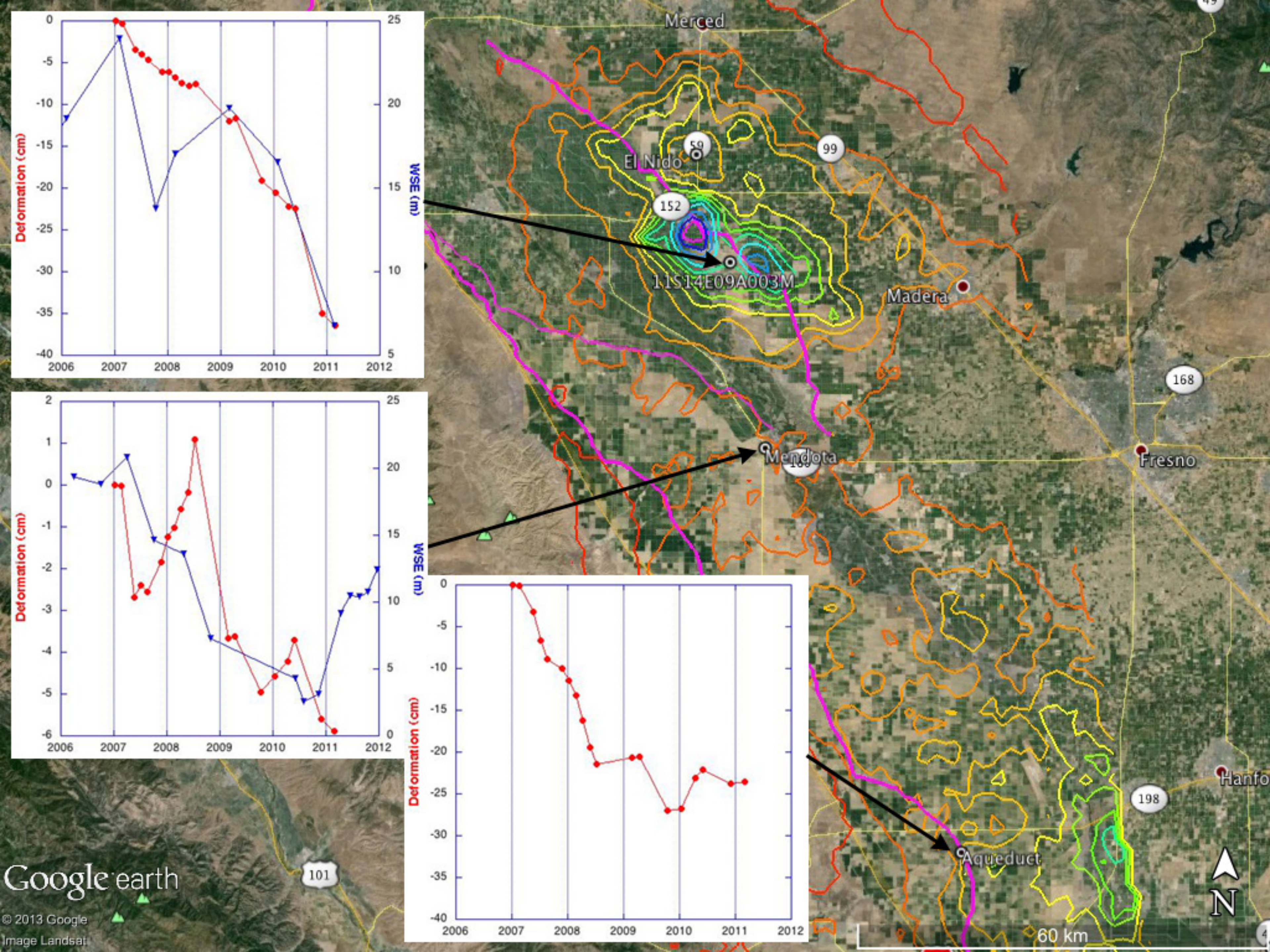
Paul Lundgren, Vince Realmuto, JPL

Subsidence in the Central Valley of California: PALSAR, 2007-2011

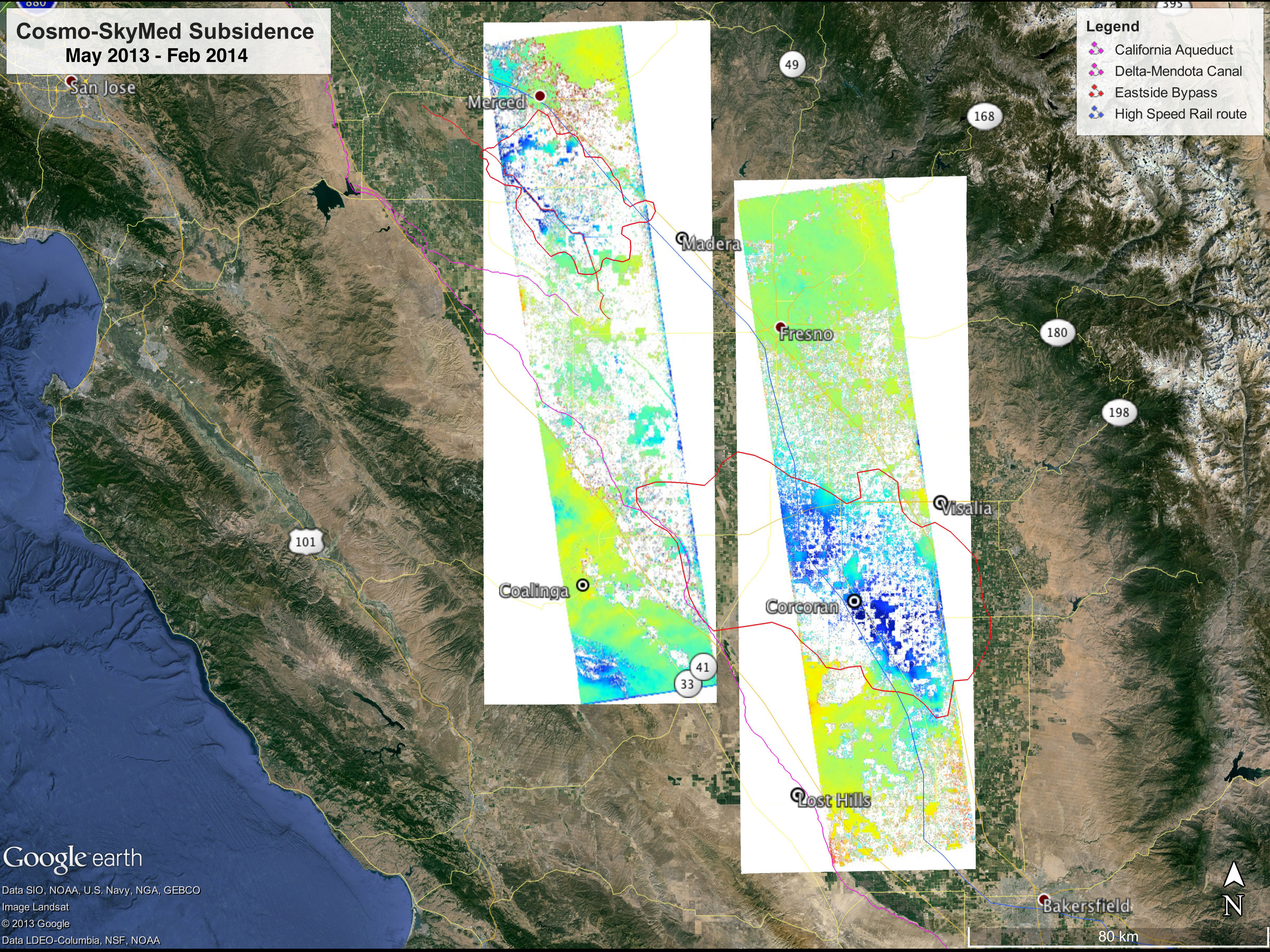


Zhen Liu, Vince Realmuto, Tom Farr, JPL


PALSAR Subsidence
2007 - 2011
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
High Speed Rail route
20 cm/yr
San Jose
Merced
Madera
Fresno
Visalia
Coalinga
Corcoran
Lost Hills
Bakersfield
49
168
180
198
5
41
33
101
80 km
N
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
© 2013 Google
Data LDEO-Columbia, NSF, NOAA



Merced
El Nido
59
99
152
11S14E09A003M
Madera
168
Mendota
Fresno
Hanfo
198
Aqueduct
101
Google earth
© 2013 Google
Image Landsat
60 km
N
Deformation (cm)
WSE (m)
2006
2007
2008
2009
2010
2011
2012


Cosmo-SkyMed Subsidence
May 2013 - Feb 2014
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
High Speed Rail route
San Jose
Merced
Madera
Fresno
Visalia
Corcoran
Coalinga
Lost Hills
Bakersfield
49
168
180
198
101
41
33
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
© 2013 Google
Data LDEO-Columbia, NSF, NOAA
80 km
N

Summary and Next Steps

- InSAR maps and measures subsidence and rebound which correlates with groundwater withdrawal and recharge
- A new project funded by the California Department of Water Resources (DWR) will extend the time series into 2014
- We are also working with DWR to define a project to build capacity to monitor subsidence into the future as is being done in Arizona
- We currently rely on data from other countries (Japan, Europe, and Canada)
- The NASA L-band SAR mission will ensure continuity of these critical data sets